

# **COMPONENT AVAILABILITY EFFECTS FOR PRESSURE RELIEF VALVES USED AT HYDROGEN FUELING STATIONS**

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## **ABSTRACT**

There are times in engineering when it seems that safety and equipment cost reduction are conflicting priorities. This could be the case for pressure relief valves and vent stack sizing. This paper explores the role that component availability (particularly variety in flow and orifice diameters) plays in the engineer's decision of a relief valve. This paper outlines the guidelines and assumptions in sizing and selecting pressure relief devices (PRDs) found in a typical high pressure hydrogen fueling station. It also provides steps in sizing the station common vent stack where the discharge gas is to be routed to prior being released into the atmosphere. This paper also explores the component availability landscape for hydrogen station designers and identifies opportunities for improvement in the supply chain of components as hydrogen fueling stations increase in number and size. American Society of Mechanical Engineers Boiler and Pressure Vessel Code Section VIII (ASME BPVC Section VIII), Compressed Gas Association S-1.3 (CGA S-1.3), and American Petroleum Institute 520 (API 520) standards provide specific design criteria for hydrogen pressure relief valves. Results of these calculations do not match the available components. The available safety relief valves are 50 to 87 times larger than the required calculated flow capacities. Selecting a significantly oversized safety relief valve affects the vent stack design as the stack design requires sizing relative to the actual flowrate of the safety relief valve. The effect on the vent stack size in turn negatively affects site safety radiation threshold set back distances.

**Nomenclature:**

PRDS	Pressure Relief Devices
PRD	pressure relief device
PRV	pressure relief valve
PSV	pressure safety valve
TPRD	temperature activated pressure relief devices
AMSE	American Society of Mechanical Engineers
AMSE BPVC	American Society of Mechanical Engineers Boiler and Pressure Vessel Code
CGA	Compressed Gas Association
API	American Petroleum Institute
MAWP	Maximum Allowable Working Pressure
AHJ	Authority Having Jurisdiction
LP	low pressure
MP	medium pressure
HP	high pressure

## 1.0 INTRODUCTION

Pressure relief devices (PRDS) are required in the United States for equipment operating above 15 psig. The American Society of Mechanical Engineers (ASME) provides guidance in the Boiler and Pressure Vessel Code (ASME BPVC) which states, “To ensure the safety of personnel, equipment and the environment, a process equipment with maximum allowable working pressure (MAWP) of 15 psig (1.03 barg or 103 kPag) or greater shall be equipped with a minimum of one pressure relief device” [1]&[2]. Many jurisdictions in the United States adopt ASME BPVC into state law through the state building and fire codes. Proper sizing and selection of a PRD is critical to proper operation as the PRD is commonly the main mitigation safeguard for prevention of rupture of the pressurized equipment during a process upset. A common type of PRD is a spring loaded valve that can either be for a liquid application or for a gas application. These spring loaded valves are commonly found on stationary equipment. These valves may be designed to re-seal after system pressure is reduced or the valves may be designed to remain open after a pressure release. Other PRDs include temperature activated pressure relief devices (TPRD) and burst discs. The scope of this document addresses pressure safety valves (PSVs) designed for gas and vapor without a combination of rupture disc and is specifically focused on PSVs installed on high pressure hydrogen fueling stations. Upon selecting appropriate PSV, proper sized PSVs discharge pipes must be considered in the overall design to ensure that the vent system conveying gas from the pressure relief device does not restrict the relief device effectiveness to direct the vented gas to a safe and approved location [3]. This paper encompasses three parts:

- Guidelines and assumptions in sizing and selecting pressure safety valves
- Guidelines and assumptions in sizing vent stack and how available PSVs impact vent stacks size and site safety radiation threshold set back distances for personnel, equipment, and public areas
- Current high pressure safety valves availability landscape for hydrogen fuelling stations

This paper closes by identifying opportunities for improvement in the supply chain as hydrogen fueling station projects increase in number and size.

## 2.0 MAIN BODY

Pressure safety valves (PSVs) play an important role in the industrial processes. The PSV is a safeguard that ensures the process pressure does not exceed systems designed maximum allowable working pressure (MAWP). Proper sizing and selection of a PSV is critical to system safety as the device is sometimes the last mitigation to prevent failure or rupture of pressurized equipment. Sizing and selecting a proper process PSV requires a good understanding of the overall process and the location where the PSV is being installed in the system.

### 2.1 Sizing and selecting process pressure safety valves

Selection of a PSV requires the design engineer to evaluate the process conditions of the pressure system against the requirements of the regulations and standards. The requirements are often determined as a required flowrate and allowable pressure increase. After determining the required flowrate, the engineer must select a PSV with the appropriate effective area or orifice diameter that at a minimum produces this required flowrate. The calculations shown here demonstrate the evolution of this selection process. Some assumptions and relief scenarios of the PSV are necessary as well. Assumptions considered in this analysis include:

- a non ideal gas with sonic flow at the PSV set pressure
- known case flowrate (W)
- isentropic flow behavior
- ambient temperature of 15 °C

- no pressure drop upstream and downstream of the PSV for conservative approach for maximum gas relief
- compressibility factor (Z) obtained from Abel-Nobel Equation of State

Finally, PSVs are grouped into common pipe on a basis of set pressure. The resulting common pipe in which PSVs discharge gas are collected on a basis of set pressure is called a *header*. Headers are then routed to a vent often called a “vent stack” which conveys released gas into the atmosphere [5]. The ASME code provides common scenarios for the design engineer to consider when sizing a pressure safety valve. In this paper we consider the commonly used “thermal expansion scenario” and “fire scenario” for proper sizing of the pressure safety valves [2]. The thermal expansion case described in this paper refers to operational emergency condition such as a process line on the cold side of an exchanger that can result in excess pressure due to heat input from the warm side. Thermal expansion examples also includes solar radiation or change in atmospheric temperature other than fire for vessels and piping containing non-liquefied compressed gases operating below 54 °C. The fire scenario refers to an operational emergency created by fire exposure of uninsulated containers for non-liquefied compressed gases. The required flowrate to prevent overpressure must be calculated for each scenario. The scenario that requires the highest flowrate is considered the worst case and the PSV must be able to discharge at least the flowrate required by the worst case. Therefore, the PSV selected to protect the equipment must have an effective discharge area at least as large as the calculated flowrate for the worst case scenario.

In a thermal expansion case, pressure safety valve sizing for vapor and gas service fall into two general categories depending on whether the flow exhibits critical or subcritical behavior. Flow exhibiting critical behavior occurs when the pressure downstream of the PSV nozzle is less, or equal to critical flow pressure,  $P_{cf}$ , which is obtained using Equation 1 [4].

$$\frac{P_{cf}}{P_1} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}, \quad (1)$$

where  $P_{cf}$  - critical flow nozzle absolute pressure, kPa;  $P_1$  - relieving upstream absolute pressure, kPa;  $k$  – gas or vapor specific heats ratio ( $C_p/C_v$ ) with  $C_p$  and  $C_v$  being the specific heat at constant pressure and constant volume respectively, 1.41 for hydrogen.

For this critical behavior case, the required PSV effective discharge area and orifice diameter is determined using Equation 2 [1] & [4].

$$A = \frac{W}{C * K_d * P_1 * K_b * K_c} * \sqrt{\frac{T * Z}{M}}, \quad (2)$$

When the flow falls into the subcritical category where downstream pressure exceeds the critical flow pressure,  $P_{cf}$ , Equation 3 is used to determine PSV required effective discharge area and orifice diameter [4].

$$A = \frac{17.9 * W}{F_2 * K_d * K_c} * \sqrt{\frac{T * Z}{M * P_1 * (P_1 - P_2)}}, \quad (3)$$

where  $A$  - required effective discharge area for thermal expansion case,  $\text{mm}^2$ ;  $W$  - required flow capacity through the PSV, kg/hr;  $C$  - function of the ideal gas specific heats ratio ( $k = C_p/C_v$ );  $K_d$  - unit less discharge coefficient, 0.8;  $P_1$  - the absolute upstream relieving pressure, kPa;  $K_b$  - unit less capacity correction factor due to backpressure, 1;  $K_c$  - unit less combination correction factor, 1;  $T$  - relieving temperature of the inlet gas or vapor, K;  $Z$  - unit less compressibility factor for the deviation of the actual

gas from an ideal gas evaluated at the relieving inlet conditions;  $M$  - gas or vapor molecular weight, kg/kg-mole;  $F_2$  - unit less coefficient of subcritical flow;  $P_2$  - absolute back pressure, kPa.

In an event where the flowrate of the system is unknown, Equation 4 is used to determine the minimum required PSV relief capacity [2]. Since most PSVs manufacturers specify PSVs relief capacities in air basis, Equation 5 is used to convert fluid flowrate into air basis to ensure proper PSVs selection.

$$W_{fluid} = \frac{0.074 * P * V}{c} \sqrt{\frac{M}{Z}} \quad , \quad (4)$$

where  $W$  - minimum required PSV relief capacity at the applicable flow rating pressure and 15 °C, m<sup>3</sup>/hr;  $P$  - maximum allowable absolute pressure of the container, kPa;  $V$  - volume of the container, m<sup>3</sup>;  $C$  - function of the ideal gas specific heats ratio ( $k = C_p/C_v$ );  $M$  - gas or vapor molecular weight, kg/kg-mole;  $Z$  - a unit less compressibility factor for the deviation of the actual gas from an ideal gas evaluated at the relieving inlet conditions.

$$W_{fluid} = W_{air} * \sqrt{\frac{\rho_{air}}{\rho_{fluid}}} \quad , \quad (5)$$

where  $W_{air}$  – minimum required PSV relief capacity at the applicable flow rating pressure and 15 °C in air basis, m<sup>3</sup>/hr;  $\rho_{air}$  – density of air at applicable flowrate pressure and 15 °C, kg/m<sup>3</sup>;  $\rho_{fluid}$  -density of the fluid at the applicable flowrate pressure and 15 °C, kg/m<sup>3</sup>.

The other scenario considered in sizing the PSV is the fire case which can be defined as an operational emergency for equipment exposed to a pool fire. For this scenario, Equation 6 is used to calculate the required PSV effective discharge area.

$$A_{prd} = \frac{2225.46 * S * A * k^2 * \sqrt{M}}{K_d * C * P} \quad , \quad (6)$$

where  $A_{prd}$  - required effective discharge flow area of the PSV, cm<sup>2</sup>;  $A$  - container outer surface area, m<sup>2</sup>;  $S$  - safeguarding factor (Typically 1, but can be reduced to 0.3 when installation factors reduce the likelihood or severity of fire);  $k$  – gas or vapor specific heats ratio ( $C_p/C_v$ ) with  $C_p$  and  $C_v$  being the specific heat at constant pressure and constant volume respectively, 1.41 for hydrogen;  $M$  – gas or vapor molecular weight, kg/kg-mole;  $C$  - function of the ideal gas specific heats ratio ( $k = C_p/C_v$ );  $K_d$  - unit less discharge coefficient of the PSV;  $P$  - maximum allowable absolute pressure of the container, kPa.

Calculated effective area values obtained from Equation 2 or 3 and 6 are compared against actual PSV manufacturer discharge area values for proper PSV selection for the application. See analysis results summary shown in Table 1 for a high pressure hydrogen station. Calculated values refer to values that were obtained from equations provided by codes and standards. In contrast, actual values refer to values that come directly from the installed device manufacturer. When specifying PSVs for high pressure hydrogen fueling systems, the selection of components becomes more challenging due to the limited number of manufacturers that offer National Board certified valves. Vendor referenced in Table 1 is the representative of the overall components availability.

Table 1. PSV effective discharge area analysis summary

Protected Equipment	Supply Storage	LP Storage	MP Storage	Compressor Suction	MP Compressor Interstage	MP Compressor Outlet	HP Compressor Outlet	HP Storage	HP Dispenser
Tag Number	PSV 1	PSV2	PSV3	PSV4	PSV5	PSV6	PSV7	PSV8	PSV9
Set Pressure(kPag)	25,000	53,600	53,600	25,000	25,000	55,000	95,000	95,000	87,500
Calculated Thermal Expansion PSV Flow Area (mm <sup>2</sup> )	0.79	0.05	0.74	2.75	1.46	0.71	0.42	0.42	0.45
Calculated Fire Case PSV Flow Area (mm <sup>2</sup> )	14.13	0.69	0.69	4.50	0.01	0.004	0.004	0.58	0.004
Actual PSV Flow Area-(mm <sup>2</sup> )**	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92
Calculated Required PSV Flowrate-(Nm <sup>3</sup> /hr)	404.6	56.1	762.1	2,599.8	762.1	762.1	710.9	710.9	710.9
Actual PSV Flowrate-(Nm <sup>3</sup> /hr)**	16,292.3	34,876.02	34,876.02	16,292.3	16,292.3	35,778	61,756.2	61,756.2	56,880.7

\*\* Fluid Mechanics 1500 Series pressure safety valves with an orifice diameter of 6.36 mm (0.25 in)

The huge discrepancy between the calculated values as compared to the installed PSVs actual values is mainly due to the lack of National Board approved components available for high pressure hydrogen service.

This discrepancy in the effective area values will result in oversizing the height of the site vent stack. The vent stack design required sizing is relative to the actual PSV flow capacity and not the flowrate required by the worst case. The next section will demonstrate that this ‘oversized’ vent stack design also creates unnecessary site radiation threshold set back distances for personnel, equipment, and public areas safety.

## 2.2 Sizing vent stack and PSVs impact on vent stacks size and radiation threshold set back distances

Due to the hazard and flammability associated with hydrogen gas, the discharge of hydrogen gas from each PSV must be routed to a safe and approved location [3]. PSV discharge gas is collected into common headers on the basis of a set pressure ratio of 1/5 and routed to a safe and approved location [6]. A good practice in sizing the process vent stack is to evaluate and identify the maximum conservative and realistic relieving flow scenario so that oversizing of the hydrogen station vent stack is avoided. The worse case considered in this analysis includes the compressor suction pressure regulator failure and simultaneous release of multiple pressure sources into the vent stack. CGA G-5.5 provides guidance on

the design of hydrogen vent systems and references API 521 2014 which contains specific design calculations for vent systems. The use of CGA G-5.5 and subsequently API 521 is common practice in the process gas industry and required by the model fire codes such as NFPA 2.

The purpose of the vent stack design is the elimination of hazards to personnel, equipment, and public areas. Not all venting events will result in a flame at the vent outlet; however the vent stack design considers a flame at the outlet as a normal condition. The radiation of that flame to the personnel, equipment, and public areas below or adjacent to the vent stack are the key exposures. Thus the vent stack design ultimately determines the required distances to these exposures based on thermal radiation dose thresholds shown in Table 2. [6]; the maximum heat exposure is directly proportional to the maximum realistic relieving flow scenario. The maximum heat released is calculated using Equation 7.

$$Q_h = LHV * Q \quad , \quad (7)$$

where  $Q_h$  - maximum heat released, kW;  $LHV$  - lower heating value of the fluid, kWh/Nm<sup>3</sup> (3 kWh/Nm<sup>3</sup> for hydrogen);  $Q$  - maximum scenario discharging flowrate, Nm<sup>3</sup>/hr.

Once the anticipated defined scenario of heat release is calculated, the next step is to calculate the minimum distance from the flame epicenter to the thermal radiation threshold location (personnel, equipment and public areas) using Equation 8.

$$D = \sqrt{\frac{\tau * F * Q_h}{4 * \pi * K}} \quad , \quad (8)$$

where  $D$  - minimum distance from the epicenter of the flame to the thermal radiation threshold safe location, m;  $\tau$  - unit less fraction of the radiated heat transmitted through the atmosphere, 1;  $F$  - unit less fraction of heat radiated (11.1%);  $Q_h$  - heat released based on the lower heating value of the fluid calculated from Equation 7, kW;  $K$  - radiant threshold heat intensity, kW/m<sup>2</sup>.

Table 2. Recommended design radiation threshold [source]<sup>6</sup>

Permissible design level k kW/m <sup>2</sup> (Btu/h.ft <sup>2</sup> )	Conditions
9,46 (3000)	Maximum radiant heat intensity at any location where urgent emergency action by personnel is required. When personnel enter or work in an area with the potential for radiant heat intensity greater than 6,31 kW/m <sup>2</sup> (2000 Btu/h.ft <sup>2</sup> ), then radiation shielding and/or special protective apparel (e.g. a fire approach suit) should be considered.  <b>SAFETY PRECAUTION - It is important to recognize that personnel with appropriate clothing <sup>a</sup> cannot tolerate thermal radiation of 9, 46 kW/m<sup>2</sup> (3000 Btu/h.ft<sup>2</sup>) for more than a few seconds.</b>
6,31 (2000)	Maximum radiant heat intensity in area where emergency actions lasting up to 30 s can be required by personnel without shielding but with appropriate clothing <sup>a</sup> .
4,73 (1500)	Maximum radiant heat intensity in area where emergency actions lasting 2 min to 3 min can be required by personnel without shielding but with appropriate clothing <sup>a</sup> .
1,58 (500)	Maximum radiant heat intensity at any location where personnel with appropriate clothing <sup>a</sup> can be continuously exposed.

<sup>a</sup> Appropriate clothing consists of hard hat, long-sleeved shirts with cuffs buttoned, work gloves, long-legged pants and work shoes.

Appropriate clothing minimizes direct skin exposure to thermal radiation.

Site specific safety and surrounding conditions must also consider flame length and wind distortion. The flame length is defined by the minimum horizontal ( $I_x$ ) and vertical ( $I_y$ ) offset distances with respect to the vent stack exit [6]. Assuming that the flame has a single radiant epicenter and not subjected to wind distortions affect, heat released value ( $Q_h$ ) obtained from Equation 7 along with Equation 9 are used to calculate the flame length,  $L_f$  associated with each radiant heat threshold (personnel, equipment, or public areas).

$$L_f = 10^{(0.444 \cdot \log(Qh) - 0.876)} \quad , \quad (9)$$

However, under wind conditions with a conservative wind velocity of 9 m/s for the analysis, the flame will be distorted as shown in Fig.1. The effects of wind distortion denoted as  $\sum \frac{\Delta x}{L_f}$  and  $\sum \frac{\Delta y}{L_f}$  in Fig.1 were taken into account when calculating the flame epicenter offset distances. The flame epicenter offset distances due to the effects of wind distortion are calculated using Equation 10 and Equation 11 along with factors associated with effects of wind distortion respectively [6].

$$I_x = 0.5 * L_f * \sum \frac{\Delta x}{L_f} \quad , \quad (10)$$

$$I_y = 0.5 * L_f * \sum \frac{\Delta y}{L_f} \quad , \quad (11)$$

where  $I_x$  - horizontal tilt flame offset distance due to wind velocity, m;  $I_y$  - vertical tilt flame offset distance due to wind velocity, m;  $L_f$  - flame length, m;  $\sum \frac{\Delta x}{L_f}$  - unit less horizontal wind distortion effect factor obtained from Figure 1;  $\sum \frac{\Delta y}{L_f}$  - unit less vertical wind distortion effect factor obtained from Figure 1.

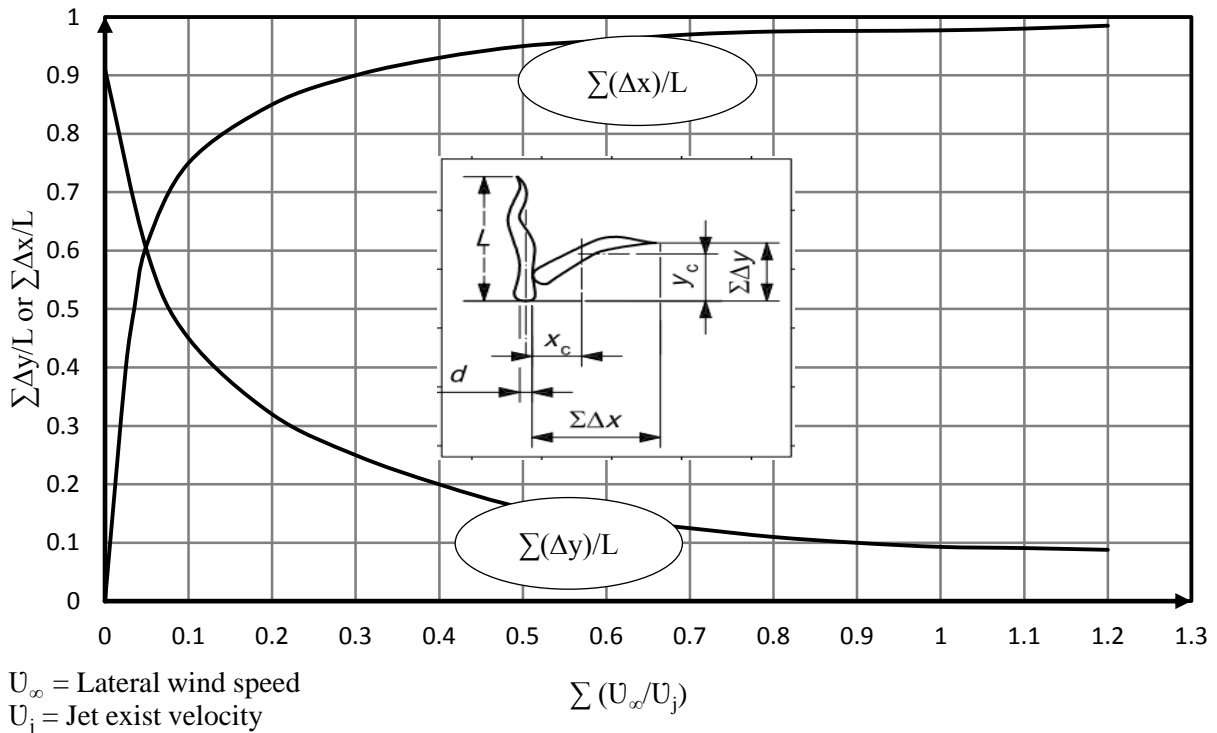


Figure 1. Flame distortion effect due to lateral wind on jet velocity from flare stack [source] <sup>6</sup>



Fig. 2 shows the relationship between the calculated radiation threshold distances  $D_H$  (personnel),  $D_I$  (Equipment) and  $D_L$  (public domain) and the applicable safety distances  $H$  (required vent stack height),  $X$  (horizontal flame offset distance due to wind velocity), and  $Y$  (vertical flame offset distance due to lateral wind velocity).

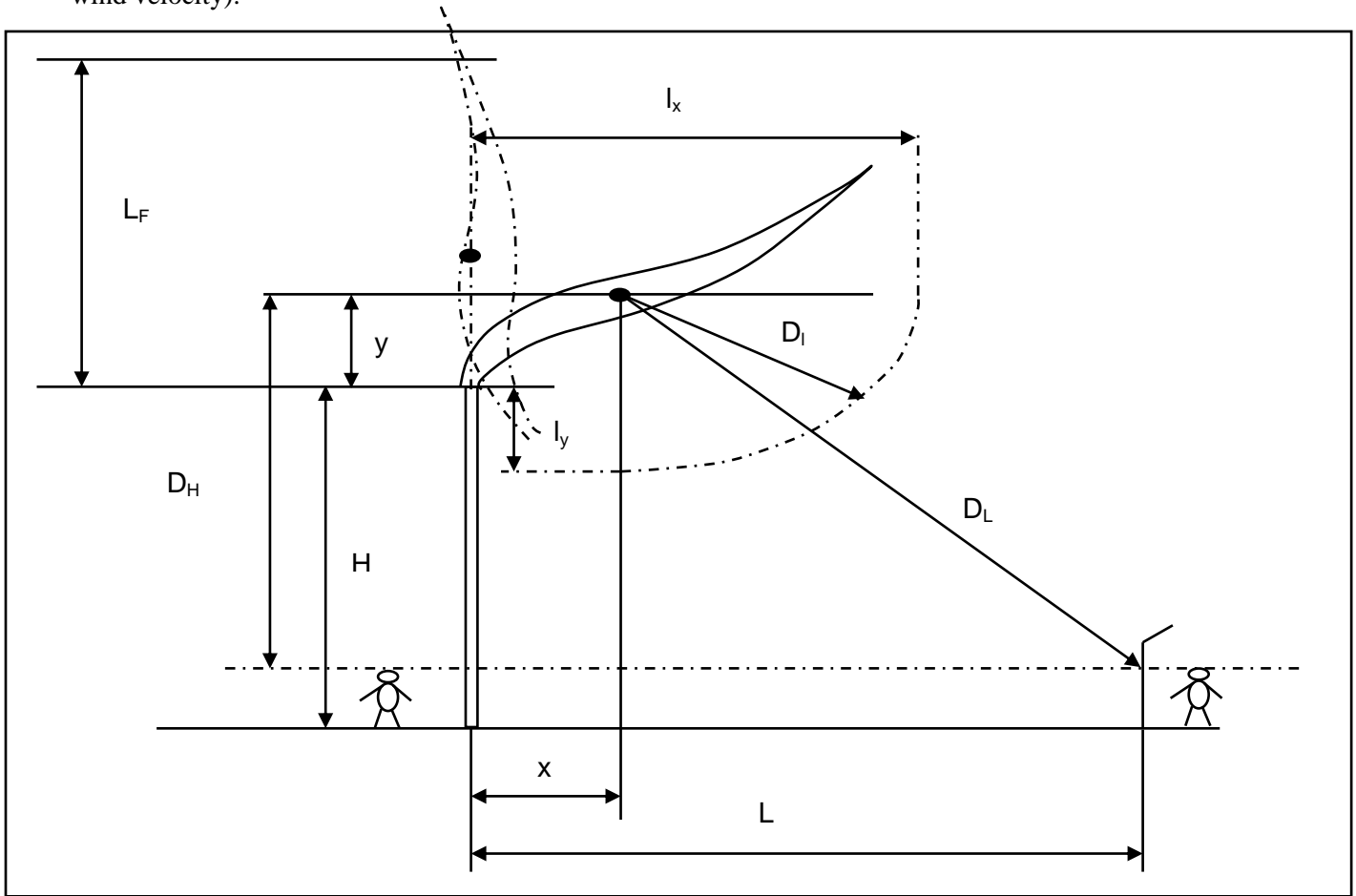


Figure 2. Radiation threshold and safe distances [source]<sup>12</sup>

The discrepancy in PSVs effective area values (required vs. actual) demonstrated in the previous section, results in oversizing site vent stack height. Oversizing the vent stack results in significantly greater site safety radiation threshold set back distances for personnel, equipment, and public areas. Take the example of worse case design of the compressor suction relieving in event of upstream pressure regulator failure with the required PSV flowrate determined to be  $2,600 \text{ Nm}^3/\text{hr}$  compared to the actual installed PSV flowrate of  $17,244 \text{ Nm}^3/\text{hr}$ . These flowrates will result in vent stacks designs shown in Table 3. From this worse case example, it can be seen that the discrepancy in PSVs effective area/orifice size (required vs. actual) resulted in oversizing the vent stack height by a factor of 2. Additionally, it creates unnecessary site safety set back distances for personnel ( $D_H$ ), equipment ( $D_I$ ), and public areas ( $D_L$ ) by a factor of 3. Moreover, it will create unnecessary expenses of the vent stack procurement and installation. Finally, unnecessary site safety radiation threshold set back distances resulted from oversized vent stacks due to oversized PSVs create challenges to incorporate high pressure hydrogen stations into existing gasoline stations.

Table 3. Impact of PSV effective area/orifice size (required vs. actual) on vent stack design

Vent Stack Design Characteristics	Compressor Suction-Calculated Required PSV Flow	Compressor Suction-Actual PSV Flow
Vent Stack Diameter (D)-mm	52.5	52.5
Flow Rate (Q)-Nm <sup>3</sup> /h	2,599.80	17,244
Heat Released (Q <sub>h</sub> )-kW	7,797	51,732
Thermal Radiation Threshold Distance from Equipment (D <sub>E</sub> )-m	2.6	6.8
Thermal Radiation Threshold Distance from Public Areas (D <sub>L</sub> )-m	6.6	16.9
Thermal Radiation Threshold Distance from Personnel (D <sub>H</sub> )-m	3.7	9.6
Flame Length (L <sub>f</sub> )-m	7.1	16.5
Vertical Offset Distance Due to Wind (Y)-m	1.3	3.0
Horizontal Offset Distance Due to Wind (X)-m	3.4	7.9
Vent Stack Height due to Personnel (H)-m	4.3	8.4
Horizontal Distance from Vent Stack to Public Domain (L)-m	8.0	23.6
Horizontal Distance from Vent Stack to Equipment (l <sub>x</sub> )-m	3.4	7.9
Vertical Distance from Vent Stack to Equipment Downward (l <sub>y</sub> )-m	2.0	3.9

### 3.0 COMPONENT AVAILABILITY

Pressure safety valves are extensively used in industries to protect pressurized systems against rupture. These valves are widely available from a number of manufacturers; however, when specifying PSVs for high pressure hydrogen fueling systems, the selection of components becomes more challenging due to the limited number of manufacturers that offer National Board certified valves and company approved vendors for hydrogen service at pressures up to 90,000 kPa. In some cases, major valve manufacturers consider the high pressure hydrogen service to be a special application such that their product offering is not included in product catalogs. For these cases, special orders in small quantities can have an adverse impact on cost and delivery. Selection of PSVs for high pressure hydrogen is further limited by the choices of orifice size. Table 1 shows typical PSV sizing for locations within a hydrogen storage and dispensing system. In the table, the referenced PSV flow area of 31.92 mm<sup>2</sup> is based on the available minimum orifice diameter of 6.375 mm (0.250 inches). This orifice size is much larger than required based on calculated required orifice sizes within the storage and dispensing system. When searching for PSVs with smaller relief valve orifice sizes that meet the high pressure hydrogen application, valve offerings are either custom products or do not have National Board certification.

As shown in the design worse case in the previous section, installing oversized PSVs due to the scarcity in component availability for high pressure hydrogen service will result in oversizing site vent stack height. This result in unnecessary site safety radiation threshold set back distances for personnel (D<sub>H</sub>), equipment (D<sub>E</sub>), and public areas (D<sub>L</sub>). Oversized site vent stacks will create unnecessary expenses due to vent sacks procurement and fabrication. It will also result in larger pipe diameters for the discharge piping and headers which will require more support for the vent system piping; therefore increasing the vent system installation cost. Finally, unnecessary site safety radiation threshold set back distances resulting from oversized vent stacks due to oversized PSVs create challenges in getting building permits from city officials to incorporate high pressure hydrogen stations into existing gasoline stations. The result is more capital expenditures are needed for new high pressure hydrogen station installations.

It must be noted that with the need of smaller PSV orifice sizes for high pressure hydrogen station applications, the process designer must take into consideration the possibility of plugging the PSV's orifice with particles. Care must be taken to eliminate start up debris and ongoing particulate generation to ensure a safe and reliable process.

## 4.0 CONCLUSIONS

Pressure relief device selection and vent stack sizing for high pressure hydrogen systems are important issues for design and siting of storage and dispensing systems. This paper discusses typical system design and shows some of the associated engineering challenges. Spring loaded pressure safety valves (PSVs) are sized based on ASME, CGA and API industry standards. National Board valves that meet the high pressure hydrogen application have orifice diameters that are 50 to 87 times larger than required by this application. These valves are being used in hydrogen systems with corresponding oversized vent systems which results in higher venting velocities. Oversized PSVs are known to be susceptible to chattering; an abnormal rapid opening and closing motions of movable parts in a PSV. The rapid vibrations may cause internal components misalignment, valve seat damage, and mechanical failure of internal and associated piping. This may result in additional operational expenditures to maintain pressure safety valve integrity for a safe and reliable process operation. In addition to the higher cost of the larger systems, the vent rates produce higher hydrogen flowrates that impact radiation threshold creating unnecessary site safety radiation threshold set back distances (personnel, equipment, and public areas) and can also increase the noise associated with venting. This creates challenges in getting building permits from Authority Having Jurisdiction (AHJs) to incorporate high pressure hydrogen stations into existing gasoline stations. This may require more capital expenditures for new high pressure hydrogen station installations.

For the case of stationary storage, there have been inadvertent releases of hydrogen due to PSV failure that have resulted in considerable system risk. Standards organizations are reviewing requirements for PSVs on stationary storage to determine the best solution for lowering the overall safety risk, considering that the risk of inadvertent PSV release can be a significant factor when conducting safety analysis. Component availability for high pressure hydrogen systems has been an issue for system designers. Hydrogen market growth should provide an incentive for an increase in the supply chain product offering. Until that time, limited PSV availability and orifice size selection is creating oversized systems that are having an impact on overall system design, thus creating unnecessary system integration and installation expenses.

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